

APPENDIX D

EQUATIONS USED IN PUMPING & FLOW COMPUTATIONS, RE-ENGINEERED DW PROJECT

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- Discharge equation :

$$Q = CA\sqrt{2gh} \dots\dots\dots(1)$$

Where,

Q = the design flow rate in cfs

C = discharge coefficient (a conservative value of C=0.6, Ref. 36)

A = Area of the gate opening in square ft

h = head available at the gate in ft

g = acceleration of gravity in feet per second (fps)

- Average velocity at the gate is given by

$$V = \frac{Q}{Wxd} \dots\dots\dots(2)$$

Where,

Q = the design flow rate in cfs

W = clear gate width (ft)

d = depth of gate opening (ft)

A = W x d

- Velocity at the pump intake is given under the design flow rate Q by

$$V = \frac{Q}{(N)\frac{\pi}{4}D^2} \dots\dots\dots(3)$$

Where,

N = number of intake pipes (pumps), and

D = diameter of intake pipes (ft).

- Manning's Equation (Ref. 36)

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2} \dots\dots\dots(4)$$

Where,

Q = the design flow rate in cfs

A = Area of the gate opening in square ft

R = hydraulic radius of the flow ft

S = slope

$$n = \frac{R^{1/6}}{23.85 + 21.95 \log(R / D_{50})} \dots\dots\dots(5).$$

(Ref. 33)

Where,
 D_{50} is the mean rock size.

- Froude Number of flow (Ref. 34)

$$F1 = \frac{V1}{\sqrt{gy1}} \dots\dots\dots(6)$$

Where,
 $V1$ = flow velocity (just downstream of a gate)
 $y1$ = flow depth prior to the jump (just downstream of a gate)
 g = acceleration of gravity in feet per second (fps)

- The sequent depth is calculated by the formula (Ref. 34):

$$y2 = 0.5y1(\sqrt{8F1^2 + 1} - 1) \dots\dots\dots(7)$$

Where,
 $y2$ = sequent depth following a hydraulic jump,
 $y1$ = flow depth prior to the jump (just downstream of a gate)
 $F1$ = Froude number of the flow (just downstream of a gate)

- Design flow rate for the pumps:

$$q = \frac{Q}{N} \dots\dots\dots(8)$$

Where,
 N = number of intake pumps, and
 Q = the design flow rate in cfs

'q' was 500 cfs for all facilities

- Bernoulli's equation to calculate the total dynamic head (TDH) on the pump unit (Ref. 35).

$$TDH = W.S.elev_{River} - W.S.elev_{Re.servoir} + H_{Loss} \dots\dots\dots(9)$$

$$TDH = W.S.elev_{River} - W.S.elev_{Re.servoir} + h_{fs} + h_{con} + h_{tr} + h_{en} + h_{ben} + h_{pipef} + h_{val} + h_{exit} \dots\dots\dots(10)$$

Where,
 h_{fs} = Head loss in Fish Screen,
 h_{con} = convergence loss from river to gate,
 h_{tr} = head loss in Trash Rack,
 h_{en} = entrance loss at pipe inlet,
 h_{ben} = bending loss in the pipe,
 h_{pipef} = pipe friction loss,
 h_{val} = valve losses,

h_{exit} = exit loss.

- Required installation pump capacity was calculated as follows:

$$hp = \frac{\gamma q h}{550 \eta} \dots\dots\dots(11)$$

$$kw = 0.746 hp \dots\dots\dots(12)$$

Where,

hp = pump horse power,
 γ = water unit weight, 62.4 lbs./c.ft,
q = design flow, cfs
h = Total dynamic head, ft
 η = combined pump and motor efficiency, 87%
kw = kilowatt.

- Head Loss in Fish Screen, h_{fs} :

Head loss in the Fish Screen was assumed to be zero since the velocity at the fish screen is only 0.2 fps which makes the velocity head ($V^2/2g$) very low.

- Head Loss during convergence from river to the gate and reservoir to gate, h_{con} :

Head loss coefficient of 0.5 was used for a square entrance (Ref. 34)

$$h_{con} = 0.5 \frac{V^2}{2g} \dots\dots\dots(13)$$

- Head Loss in the Trash Rack, h_{tr} (Ref. 35):

$$h_{tr} = K_t \frac{V_n^2}{2g} \dots\dots\dots(14)$$

Where,

K_t = trash rack loss coefficient (Ref. 35),

$$K_t = 1.45 - 0.45 \left(\frac{a_n}{a_g} \right) - \left(\frac{a_n}{a_g} \right)^2 \dots\dots\dots(15)$$

Where,

a_n =area through the trash rack bars,
 a_g =gross area of trash rack and supports,
 V_n =velocity through the net trash rack area.

- Entrance Loss due to sudden contraction at pipe inlet, h_{en} (Ref. 34):

$$h_{en} = 0.31 \frac{V^2}{2g} \dots\dots\dots(16)$$

- Bending Loss in pipe, h_{ben} (Ref. 37):

$$h_{ben} = 0.4 \frac{V^2}{2g} \dots\dots\dots(17)$$

- Head Loss due to pipe friction, h_{pipef} (Ref. 37):

$$h_{pipef} = \frac{4.66n^2Q^2L}{D^{16/3}} \dots\dots\dots(18)$$

- Valve Loss, h_{val} (Ref. 37):

$$h_{val} = 0.2 \frac{V^2}{2g} \dots\dots\dots(19)$$

- Exit Loss, h_{exit} :

$$h_{exit} = 1.0 \frac{V^2}{2g} \dots\dots\dots(20)$$